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Abstract:

Objective

To evaluate the incidence of brachial plexus birth injury (BPBI) and its associations with maternal demographic factors. Additionally, we sought to determine whether longitudinal changes in BPBI incidence differed by maternal demographics.

Methods

We conducted a retrospective cohort study of over 8 million maternal-infant pairs using California's Office of Statewide Health Planning and Development Linked Birth Files from 1991-2012. Descriptive statistics were used to determine BPBI incidence and the prevalence of maternal demographic factors (race, ethnicity, age). Multivariable logistic regression was used to determine associations of year, maternal race, ethnicity, and age with BPBI. Excess population level risk associated with these characteristics was determined by calculating population attributable fractions.

Results

The incidence of BPBI between 1991-2012 was 1.28 per 1000 live births, with peak incidence of 1.84 per 1000 in 1998 and low of 0.9 per 1000 in 2008. Incidence varied by demographic group, with infants of Black (1.78 per 1000) and Hispanic (1.34 per 1000) mothers having higher incidences compared to White (1.25 per 1000), Asian (0.8 per 1000), Native American (1.29 per 1000), Other race (1.35 per 1000), and Non-Hispanic (1.15 per 1000) mothers. After controlling for delivery method, macrosomia, shoulder dystocia, and year, infants of Black (AOR=1.88, 95% CI 1.70, 2.08), Hispanic (AOR=1.25, 95% CI 1.18, 1.32) and advanced-age mothers (AOR=1.16, 95% CI 1.09, 1.25) were at increased risk. Disparities in risk experienced by Black, Hispanic, and advanced-age mothers contributed to a 5%, 10%, and 2% excess risk at the population level, respectively. Longitudinal trends in incidence did not vary among demographic groups. Population-level changes in maternal demographics did not explain changes in incidence over time.

Conclusions

Although BPBI incidence has decreased in California, demographic disparities exist. Infants of Black, Hispanic, and advanced-age mothers are at increased BPBI risk compared to White, Non-Hispanic, and younger mothers.

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Maternal Epidemiology of Brachial Plexus Birth Injuries in California: 1996-2012

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Abstract

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maternal race, ethnicity, and age with BPBI. Excess population level risk associated with these characteristics was determined by calculating population attributable fractions.

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The incidence of BPBI between 1991-2012 was 1.28 per 1000 live births, with peak incidence of 1.84 per 1000 in 1998 and low of 0.9 per 1000 in 2008. Incidence varied by demographic group, with infants of Black (1.78 per 1000) and Hispanic (1.34 per 1000) mothers having higher incidences compared to White (1.25 per 1000), Asian (0.8 per 1000), Native American (1.29 per 1000), Other race (1.35 per 1000), and Non-Hispanic (1.15 per 1000) mothers. After controlling for delivery method, macrosomia, shoulder dystocia, and year, infants of Black (AOR=1.88, 95% CI 1.70, 2.08), Hispanic (AOR=1.25, 95% CI 1.18, 1.32) and advanced-age mothers (AOR=1.16, 95% CI 1.09, 1.25) were at increased risk. Disparities in risk experienced by Black, Hispanic, and advanced-age mothers contributed to a 5%, 10%, and 2% excess risk at the population level, respectively. Longitudinal trends in incidence did not vary among demographic groups. Population-level changes in maternal demographics did not explain changes in incidence over time.

Conclusions

Although BPBI incidence has decreased in California, demographic disparities exist. Infants of Black, Hispanic, and advanced-age mothers are at increased BPBI risk compared to White, Non-Hispanic, and younger mothers.

Key words:

Brachial plexus birth injury; epidemiology; maternal demographic characteristics; perinatal outcomes; health disparities

Key points:

- The incidence of BPBI has decreased over time
- Demographic disparities in BPBI incidence and risk exist
- Infants of Black, Hispanic, and advanced age mothers are at greatest risk of BPBI

Introduction

Brachial plexus birth injury (BPBI) results from trauma to the nerve roots of the brachial plexus during childbirth and presents as flaccid weakness of the upper extremity. BPBI occurs in 1.5 per 1000 livebirths in the United States,[1,2] with similar incidences reported internationally.[3] Although the majority recover spontaneously within the first few months of life, infants with more severe injuries

have permanent weakness and sensory deficits even with surgical intervention.[4–9] Moreover, chronic denervation in a skeletally immature child results in impaired musculoskeletal development,[10,11] including reduced upper extremity growth, joint contractures, skeletal dysplasia, functional limitations [12–14] and psychosocial[12,14,15] consequences persisting into adulthood.[16]

The epidemiology of BPBI is incompletely understood. Although the demographic characteristics of affected infants have been described,[2,17] less is known about the association of maternal demographic factors. Improved understanding of maternal characteristics may be more clinically impactful than infant factors, as they can be identified prenatally, allowing development of prevention strategies. Additionally, understanding of BPBI risk factors is incomplete,[18] limited principally to intrapartum factors, such as shoulder dystocia, prolonged labor, instrumented delivery, and fetal macrosomia, [19–24] few of which are identifiable prenatally. Medical obstetric complications that can be diagnosed prenatally, such as maternal obesity, excessive pregnancy weight gain, and gestational diabetes, have poor predictive ability for BPBI.[20,25–27] Fewer than 50% of affected infants have one of these known risk factors, indicating that other risk factors have yet to be identified.[1,2,20] Finally, studies of BPBI incidence using the Kid Inpatient Dataset, a national administrative claims dataset of pediatric inpatient discharges, [1,2] have identified a decrease in the incidence of BPBI and concomitant changes in Cesarean section and macrosomia rates at the population level;[2,28] it is unclear if other factors contribute to this decrease and if this decrease varies by maternal demographic characteristics.

The purpose of this investigation was to describe the incidence of BPBI in California over time, and its association with maternal demographic characteristics, including race, ethnicity, and age. Additionally, we sought to determine if longitudinal trends in BPBI incidence were comparable among demographic groups, and if population level changes in demographics contributed to a changing incidence of BPBI over time.

Methods

After obtaining approval from the University of California Davis Institutional Review Board and the California Committee for the Protection of Human Subjects, we conducted a retrospective cohort study of all maternal-livebirth infant pairs whose childbirth occurred in a California-licensed hospital from 1991 to 2012.

Dataset and study cohort

This cohort was assembled from California's Office of Statewide Health Planning and Development (OSHPD) Linked Birth Files, a dataset of linked maternal-infant data from 1991 through 2012 created to facilitate research on delivery and birth outcomes.[29–34] This dataset contains maternal demographic and health data for 9 months prior to and 12 months following delivery and is linked to the infant's demographic and health data from birth through the first year of life.[29–33] The data were compiled by OSHPD from the California Inpatient Discharge Dataset, Birth Certificate Dataset, and Vital Statistics Birth Cohort File. All maternal and infant records at non-federal, California-licensed hospitals from

1991-2012 are included, accounting for 98% of California births. Previous studies have demonstrated its accuracy for obstetrical complications, maternal factors, and intrapartum events.[35–37]

We identified all maternal-infant pairs with an infant with an ICD-9 code indicating "livebirth" during an inpatient admission (V30, V31, V33, V34, V36, V37, V39). Stillbirth infants and unlinked mothers or infants were excluded. Demographic factors in the dataset were obtained from inpatient discharge data which were self-reported by the mother and included: maternal age, race, and ethnicity and infant sex, race, and ethnicity. Mothers less than 13 and greater than 50 years old were excluded. Because the relationship of maternal age and BPBI log-odds would not be expected to be well-approximated by a linear term, maternal age was classified into three categories: young (≤ 19 years old), reference (20 – 34 years old), and advanced (≥ 35 years old). Birth characteristics and intrapartum factors included method of delivery (vaginal or cesarean), shoulder dystocia, infant birth weight, and macrosomia (>4000g). Infants who sustained BPBI were identified by ICD-9 code (767.6 or 953.4).

Statistical Analysis

Total and annual incidences of BPBI were calculated for 1991 to 2012, the years for which linked-maternal infant data is available. Because the data collection items for maternal race and ethnicity changed in 1995, in all analyses involving maternal demographic factors, we restricted the analysis to the period from 1996 to 2012. Descriptive statistics for maternal age, infant sex, and maternal and infant race and ethnicity were reported for this period and for each of four years selected to highlight the BPBI trends in our study period: 1996 (first year of the study), 1998 (year of peak BPBI incidence), 2005 (year the decrease began to level off), and 2012 (last year of the study).

Multivariable logistic regression models were used to determine the association of maternal race, ethnicity, and age with BPBI, controlling for year, shoulder dystocia, and covariates associated with the decrease in BPBI incidence in previous studies (method of delivery, infant macrosomia).[2] Although the dataset includes mothers who gave birth to more than one infant, we did not adjust for clustering of infants within a mother, which slightly underestimates standard errors for some estimates; however, we verified empirically that the underestimation was negligible. (Appendix A)

To understand the relationship of demographic factors and BPBI incidence over time at the population level, we evaluated changes in the magnitude of the association (relative risk) of demographic factors with BPBI, and changes in the distribution of demographic factors (prevalence within the population). To examine the former, we fit models that included interaction terms between year and maternal race, ethnicity, and age. For the latter, as well as the combined effect of these two possibilities, we quantified the proportion of BPBI that can be attributed to each maternal demographic factor at the population level over time by calculating the population attributable fraction (PAF) at each of the four highlighted years. Because PAF incorporates both the prevalence and relative risk of each demographic

factor, changes over time in the PAF reflect both possible ways that demographic factors could account for changes in BBPI incidence.

Results

Incidence of BPBI

From 1991-2012, there were 10,320,639 infants born to 6,967,650 individuals. The mean ($\pm$ standard deviation) number of infants per individual was 1.42 $\pm$ 0.82 infants. 13,299 infants were diagnosed with BPBI (1.28 per 1000). The incidence changed over time, increasing from 1.28 per 1000 in 1991 to 1.84 per 1000 in 1998, then declining to 0.89 per 1000 in 2008 and remaining relatively steady thereafter. (Figure 1).

From 1996-2012, 8,483,946 infants were born to 5,914,130 individuals; the mean number of infants per person was 1.43 $\pm$ 0.76 infants; 10,681 infants were diagnosed with BPBI during their birth admission (1.24 per 1000). In the multivariable model, BPBI incidence was associated with year (AOR=0.97, 95% CI 0.97 to 0.98), indicating a declining adjusted risk over the period of analysis.

Prevalence of maternal demographic characteristics

Maternal and infant demographic characteristics are included in tables 1 and 2. The relative frequencies of maternal demographic characteristics changed over time. (Table 3) The relative frequency of mothers self-identifying as Asian or Other race, became more prevalent from 1996 to 2012, while the proportion of mothers identifying as Black or White decreased. The proportion of young mothers decreased, whereas that of advanced-age mothers and Hispanic mothers increased.

Association of BPBI and maternal demographic characteristics

BPBI incidence varied by race, ethnicity, and age. (Figure 2-4) It was highest in infants of Black mothers (1.75 per 1000), followed by Other race (1.35 per 1000), Native American (1.29 per 1000), White (1.25 per 1000) and Asian mothers (0.80 per 1000). Hispanic mothers had a higher incidence (1.34 per 1000) compared to non-Hispanic mothers (1.15 per 1000). The incidence was highest in infants of advanced-age mothers (1.28 per 1000) compared to young mothers (1.14 per 1000) and mothers in the reference age group (1.24 per 1000). BPBI incidence in each demographic group decreased over time.

After controlling for delivery method, macrosomia, shoulder dystocia, and year, the adjusted odds of BPBI differed by race, ethnicity, and age. (Table 4) Compared to White mothers, the adjusted odds of BPBI were highest among Black mothers (AOR=1.88, 95% CI 1.70, 2.08) and Other race mothers (AOR= 1.14, 95% CI 1.06, 1.21). There were no significant differences in BPBI odds among Native American and Asian mothers. The adjusted odds of BPBI were 25% higher in Hispanic (AOR=1.25, 95% CI 1.18, 1.32) compared to non-Hispanic mothers. In the adjusted model, advanced maternal age was associated with 16% increased odds (AOR=1.16, 95% CI 1.09, 1.25) compared to the reference group. These adjusted associations of race, ethnicity, and age with BPBI remained stable over time; there were no significant interactions between demographic characteristics and year (Appendix B). All demographic groups experienced comparable longitudinal trends in BPBI incidence. (Appendix C)

Population-level risk of BPBI due to maternal demographic factors

The excess risk of BPBI at the population level varied by demographic factors. Those with higher estimated relative risk (Black, Hispanic and advanced-age mothers) had the greatest contribution to population level excess risk. (Table 5)

Discussion

Using a large, diverse cohort of maternal-infant pairs over a 17-year period, we identified maternal demographic characteristics associated with BPBI and characterized the relationship between these demographic factors and BPBI incidence at the individual and population level. We highlight three key findings of this study. First, the incidence of BPBI changed over time. After an initial increase from 1991-1998, it leveled off in 2005, resulting in an overall decrease over the study interval. This change was experienced similarly among demographic groups and is not explained by shifts in demographic proportions at the population level. Second, we identified increased odds of BPBI among infants born to Black, Hispanic, and advanced-age mothers, after controlling for changes over time and known risk factors. Our third key finding is that disparities in BPBI risk between racial, ethnic, and age groups contribute to the disease burden at the population level. Specifically, the excess fraction of BPBI cases that could be eliminated if risk disparities in Black, Hispanic, and advanced-age mothers were rectified are approximately 5%, 10%, and 2%, respectively.

Our finding that the incidence of BPBI decreased over time is consistent with previous studies. Foad et al[1] examined longitudinal trends in BPBI incidence from 1997 to 2003 using infant-only data from the Kid Inpatient Database (KID), which provides an annual estimated sample of pediatric discharge data every 3 years. They found that BPBI incidence decreased from 0.17% in 1997 to 0.13% in 2003 and an increased BPBI risk with shoulder dystocia and decreased risk with Cesarean delivery; they did not explore whether variation in longitudinal incidence of these factors was associated with decrease in BPBI incidence. De Francesco and colleagues[2] extended Foad's work by adding 3 more time points (2006, 2009, and 2012) and evaluating the relationship between longitudinal trends in BPBI incidence and changes in the incidence of Cesarean delivery and infant macrosomia. They found the incidence of BPBI further declined to 0.09% in 2009 and 2012, and identified a concomitant increase in Cesarean delivery and decrease in infant macrosomia, which they propose as an explanation for the decreasing BPBI rate.

In contrast to the KID dataset, the OSHPD dataset permits direct calculation of annual relative frequencies of demographic factors and BPBI, giving our study greater resolution in characterizing the trajectory of change. The similarities of our findings with previous work suggest that the trends observed in California are reflective of those observed nationally. The present study adds to the previous work by relating maternal demographic characteristics to these trends. We found that demographic groups varied in their BPBI risk but experienced a comparable decrease over time. Changes in the proportions of high and low risk groups do not account for the overall trend in BPBI incidence, and similar trends among demographic groups indicate that factors responsible for the decreasing incidence of BPBI had a comparable effect on all demographic groups. Nevertheless, an incidence of nearly 1 per 1000 live births (and higher in many demographic groups) represents a substantial burden, especially considering the potential lifelong morbidity of this condition.

Our second finding is that BPBI risk varies by demographic characteristics, with Black, Hispanic, and advanced-age mothers at higher risk of having an infant with BPBI. This is consistent with previous studies examining demographic characteristics of *infants* with BPBI.[2,17] Lalka et al. reviewed the birth claims of 966,447 infants born between 2000 and 2014 from the Colorado Hospital Administration data, and reported that Asian, Black, Hispanic, Native American and Other race infants had increased odds of BPBI compared to White infants.[17] DeFrancesco's study[2] using KID data found an increased odds of BPBI in Black (OR: 1.88) and Hispanic (OR 1.35) infants, despite lower rates of macrosomia and comparable rates of shoulder dystocia.

Fewer studies, however, have examined *maternal* demographic characteristics associated with BPBI.[21,38,39] Understanding maternal factors may be more clinically relevant than infant characteristics because this information is known prenatally and could inform prevention strategies. Freeman et al[21] used linked maternal infant data from three state inpatient databases over 2 years (Michigan 2010-2011; New Jersey 2010-2012; Hawaii 2010-2012) and reported that non-White individuals had an increased risk of delivering an infant with BPBI compared to White individuals, but did not stratify racial or ethnic background further. Volpe and colleagues [38] used a subset (1997-2006) of the same linked maternal-infant data from OSHPD used here to evaluate differences in BPBI risk among deliveries complicated by shoulder dystocia. They found that Hispanic and Black individuals had a greater risk of BPBI even after controlling for infant birth weight. Building on these studies, we evaluated maternal demographic associations over a longer period and in all livebirths, not only those complicated by shoulder dystocia, recognizing that shoulder dystocia is a common, but not exclusive, mechanism of BPBI. We also observed demographic differences, including that Black mothers had almost twofold odds of delivering an infant with BPBI, Hispanic mothers had 25% increased odds, and advanced maternal age mothers had 16% increased odds. The strength of these associations was consistent over the study interval.

Our third important finding is to quantify the effect of demographic disparities in BPBI risk in terms of excess risk to the population. We found that the population experiences a 5%, 10%, and 2% increased risk due to the demographic disparities experienced by Black, Hispanic, and advanced-age mothers, respectively. Since BPBI occurs relatively commonly, is not curable even with surgery and intensive rehabilitation, and has long-term health consequences, this excess population risk accounts for substantial morbidity.

Strengths of this study include the use of linked maternal-infant data, as opposed to the infant-only data.[2,6,17,40] Infant-only datasets often do not include maternal data sufficient to evaluate maternal risk factors and their impact on infant medical conditions.[37] The large size of this dataset allows us to identify associations that may not be powered in smaller datasets. Moreover, our dataset's continuous coverage of maternal-infant birth dyads over a 17-year period, as opposed to the triennial samples in the KID, allows better temporal resolution and enhanced characterization of trends. Additionally, the OSHPD dataset compiles data from several sources, including both maternal and infant inpatient

hospital discharges and birth certificates, which allows cross-checking accuracy among overlapping variables and broader coverage from the non-overlapping variable, an improvement over studies using a single data source. Indeed, previous investigations report that combining these two types of data provides more accurate and comprehensive maternal information than is provided by a single source.[41,42] Another strength is the diversity of maternal-infant pairs in our dataset. As California is one of the most racially, ethnically, culturally, and economically diverse states in the United States,[43] the maternal-infant population in the OSHPD Linked Birth Files allows demographic-specific estimates potentially relevant for the broader U.S. population.

Limitations of this study include its retrospective design and limitations inherent in the use of large administrative datasets. OSHPD's Linked Birth files include data from sources created for the purpose of medical billing or resource allocations. Many variables relevant to our investigation were not included in the dataset; pregnancy weight gain, body mass index (BMI), and maternal obesity were available only for a limited number of years, and therefore we could not include this variable in our assessment of BPBI risk over time. Misclassification bias is inherent in billing data, and it is possible that variables were coded incorrectly or omitted. Our cohort only included infants with BPBI diagnosed during delivery so may have missed infants with more mild injuries not diagnosed at birth and may have included infants with BPBI that ultimately resolved spontaneously. However, because BPBI is most commonly diagnosed at birth, is not easily confused with other diagnoses, has unique ICD-9 codes, and does not require confirmatory testing, we believe the accuracy for this diagnosis is likely high. The accuracy of this dataset for obstetric complications and birth diagnoses has been characterized in previously studies;[35–37] notably, severe obstetric complications were more reliably recorded than less severe complications, and maternal factors and delivery details were more reliably coded in the maternal record than the infant record.[37] Another limitation is that some variable definitions, including race and ethnicity, changed in 1995, requiring us to limit our analyses to a sub-period (1996-2012) with consistent definitions. Also, the dataset contains only maternal-infant pairs in which the birth occurred in a California-licensed facility; mothers who gave birth in a federally-licensed facility or home are not included and thus the births in this study may not be representative of those births.

Our study found that the incidence of BPBI in California has decreased over time. We identified demographic differences in BPBI risk that were consistent over the period of the study, adding to the body of literature demonstrating demographic disparities in adverse perinatal outcomes. Our findings suggest additional risk factors experienced disproportionately by Black, Hispanic, and advanced-age mothers exist that contribute to BPBI risk at the individual and population levels. The demographic disparities observed in this study may arise from several causes, including underlying health and medical comorbidities, anatomic, physiologic, or genetic susceptibility, healthcare access and utilization, personal and family preferences, and social determinants of health, as well as the interaction of these factors with known obstetric factors. These population subsets should be the

focus of future studies to inform the development and implementation of prevention strategies to decrease BPBI incidence and disparities.

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Figure 1: Incidence of Brachial Plexus Birth Injury from 1991-2012

Maternal Characteristics	
	Mean (SD)
Age (years) n=5,239,906	28.3 (6.2)
	No. (%)
Age Category n=5,239,906	
< 19 years	458,036 (8.7)
20-34 years	4,069,865 (77.7)
> 35 year	712,005 (13.6)
Race n=8,483,946	
Asian	878,602 (10.4)
Black	480,791 (5.7)
Native American	36,557 (0.4)
Other	1,601,685 (18.9)
White	5,486,311 (64.7)
Ethnicity n=8,483,946	
Hispanic	3,852,582 (45.4)
Non-Hispanic	4,631,364 (54.6)

Figure 2: Incidence of Brachial Plexus Birth Injury by Maternal Race from 1996-2012

Figure 3: Incidence of Brachial Plexus Birth Injury by Maternal Ethnicity from 1996-2012

Figure 4: Incidence of Brachial Plexus Birth Injury by Maternal Age Category from 1996-2012

Tables

Table 1: Maternal characteristics of the study cohort

Table 2: Infant characteristics of the study cohort

Infant Characteristics	
	No. (%)
Sex	
n=10,320,563	
Male	5,282,331 (51.18)
Female	5,038,232 (48.82)
Race	
n=10,176,091	
Asian	1,059,982 (10.42)
Black	649,440 (6.38)
Native American	44,206 (0.43)
Other	1,552,994 (15.26)
White	6,869,469 (67.51)
Ethnicity	
n=8,796,264	
Hispanic	3,987,696 (45.33)
Non-Hispanic	4,808,568 (54.67)
	Mean (SD)
Gestational Age (weeks)	
n=5,134,686	38.9 (1.96)
Birthweight (grams)	

n=5,233,254 3379.7 (514.1)

Table 3: Relative Frequency of Maternal Demographic Characteristics by Year

Relative Frequency (Percent) of Maternal Demographic Characteristics by Year

	1996	1998	2005	2012	1996-2012
≤ 19 years	11.3	10.8	6.7	4.3	8.7
20-34 years	77.9	77.5	78.3	78.0	77.7
≥ 35 years	10.8	11.7	15.0	17.7	13.6
Race					
Asian	9.0	9.0	10.0	12.8	10.4
Black	6.5	6.4	5.1	5.6	5.7
Native American	0.5	0.6	0.4	0.6	0.4
Other	15.6	15.6	20.9	20.8	18.9
White	68.4	68.4	63.6	60.1	64.7
Ethnicity					
Hispanic	43.2	43.1	46.8	44.2	45.4
Non-Hispanic	56.8	56.9	53.2	55.8	54.6

Table 4: Unadjusted and Adjusted Odds of BPBI by Maternal Demographic Characteristics

Unadjusted and Adjusted Odds Ratios by Maternal Demographic Characteristics

	OR (95% CI)	p value	AOR (95%CI)	p value
Race				
Asian/Pacific Islander	0.73 (0.68, 0.79)	<.0001	0.96 (0.87, 1.06)	0.3943
Black	1.37 (1.27, 1.47)	<.0001	1.88 (1.70, 2.08)	<.0001
Native American	1.25 (0.97, 1.63)	0.0893	0.99 (0.70, 1.41)	0.9644
Other	1.14 (1.08, 1.19)	<.0001	1.14 (1.06, 1.21)	0.0001
White	Reference		Reference	
Ethnicity				
Hispanic	1.12 (1.07, 1.16)	<.0001	1.25 (1.18, 1.32)	<.0001
Non-Hispanic	Reference		Reference	
Age Category				
≤ 19 years	0.92 (0.84, 1.01)	0.064	0.96 (0.87, 1.05)	0.3432
≥ 35 year	1.03 (0.96, 1.11)	0.3836	1.16 (1.09, 1.25)	<.0001

20-34 years	Reference		Reference	
Year of Birth	0.95 (0.946, 0.953)	<.0001	0.97 (0.97, 0.98)	<.0001
Shoulder Dystocia	73.6 (69.4, 78.0)	<.0001	17.6 (16.4, 18.9)	<.0001
Macrosomia	6.47 (6.21, 6.75)	<.0001	7.42 (7.04, 7.82)	<.0001
Cesarean Delivery	0.12 (0.12, 0.14)	<.0001	0.14 (0.12, 0.15)	<.0001
OR= Unadjusted Odds Ratio; AOR=Adjusted Odds Ratios which were estimated in a single model with all the variables shown simultaneously as well as year of birth, macrosomia, shoulder dystocia, and method of delivery.				

Table 5: Population Attributable Fraction by Year

	Population Attributable Fraction by Year				
	1996	**1998**	**2005**	**2012**	**19**
			% (95% CI)		
Race					
Asian	-0.4% (-1.2%, 0.5%)	-0.5% (-1.2%, 0.5%)	-0.4% (-1.3%, 0.5%)	-0.5% (-1.7%, 0.7%)	-0.4% (
Black	5.4% (4.3%, 6.5%)	5.3% (4.2%, 6.4%)	4.3% (3.4%, 5.2%)	4.7% (3.7%, 5.6%)	4.8% (
Native American	0.0% (-0.2%, 0.2%)	0.0% (-0.2%, 0.2%)	0.0% (-0.1%, 0.1%)	0.0% (-0.2%, 0.2%)	0.0% (
Other	2.1% (1.0%, 3.2%)	2.1% (1.0%, 3.2%)	2.8% (1.3%, 4.2%)	2.8% (1.3%, 4.2%)	2.5% (
White			Reference		
Ethnicity					
Hispanic	9.6% (7.1%, 11.9%)	9.6% (7.1%, 11.9%)	10.3% (7.7%, 12.8%)	9.8% (7.3%, 12.2%)	10.1% (
Non-Hispanic			Reference		
Age category					
≤ 19 years	-0.5% (-1.5%, 0.5%)	-0.5% (-1.4%, 0.5%)	-0.3% (-0.9%, 0.3%)	-0.2% (-0.6%, 0.2%)	-0.4% (
≥ 35 years	1.7% (0.9%, 2.6%)	1.9% (1.0%, 2.8%)	2.4% (1.2%, 3.6%)	2.8% (1.5%, 4.2%)	2.2% (
20-34 years			Reference		

Appendix

A. Explanation of the lack of adjustment for clustering of infants within a mother

Although the dataset includes mothers who gave birth to more than one infant, for reasons of computational feasibility and in view of the empirical results described below, we did not adjust for clustering of infants within a mother.

Hierarchical logistic regression models that could account for clustering are computationally intensive and impractical, as the required time to convergence for fitting models on the entire data set with cluster-adjusted variance estimates would frequently exceed 24 hours. To evaluate empirically the potential impact of clustering on our standard error estimates, we computed 30 independent estimates of the intraclass correlation coefficient (ICC) and variance inflation factor (VIF) by drawing 30 independent simple random samples of 30,000 mothers from the larger dataset and, for each sample, fitting a cluster-adjusted model on all the mother-child dyads from the selected mothers. This allowed us to gauge the degree of underestimation of the standard errors and confidence intervals that results from analyses that ignore clustering. This process of subsampling and fitting cluster-adjusted models was repeated 30 times. The average ICC across the 30 subsamples was used to estimate the typical VIF, the square root of which approximates how much our standard errors would need to be expanded to account for clustering. Because the typical ICC and VIF were so negligible (0.02 and 1.01, respectively), we opted not to inflate our reported standard errors to account for clustering.

B. Association of demographic characteristics and BPBI remained stable over time

The interaction terms for each demographic characteristic and year were not significant in the multivariable model, indicating that we cannot reject the homogeneity null hypothesis that the adjusted associations of race, ethnicity, and age with BPBI remained stable over time.

Race

Joint Tests			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
year	1	3.6331	0.0566
mrace	4	2.7113	0.6072
year*mrace	4	2.7151	0.6066
mhisp	1	63.0062	<.0001
mage3	2	20.5136	<.0001
macro	1	5748.9460	<.0001
csect	1	1095.6231	<.0001
shoulder_dys	1	5866.7638	<.0001

Ethnicity

Joint Tests			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
year	1	75.5153	<.0001
mhisp	1	1.3633	0.2430
year*mhisp	1	1.3194	0.2507
mrace	4	167.1612	<.0001
mage3	2	20.4757	<.0001
macro	1	5749.3746	<.0001
csect	1	1095.5404	<.0001
shoulder_dys	1	5867.8261	<.0001

Age

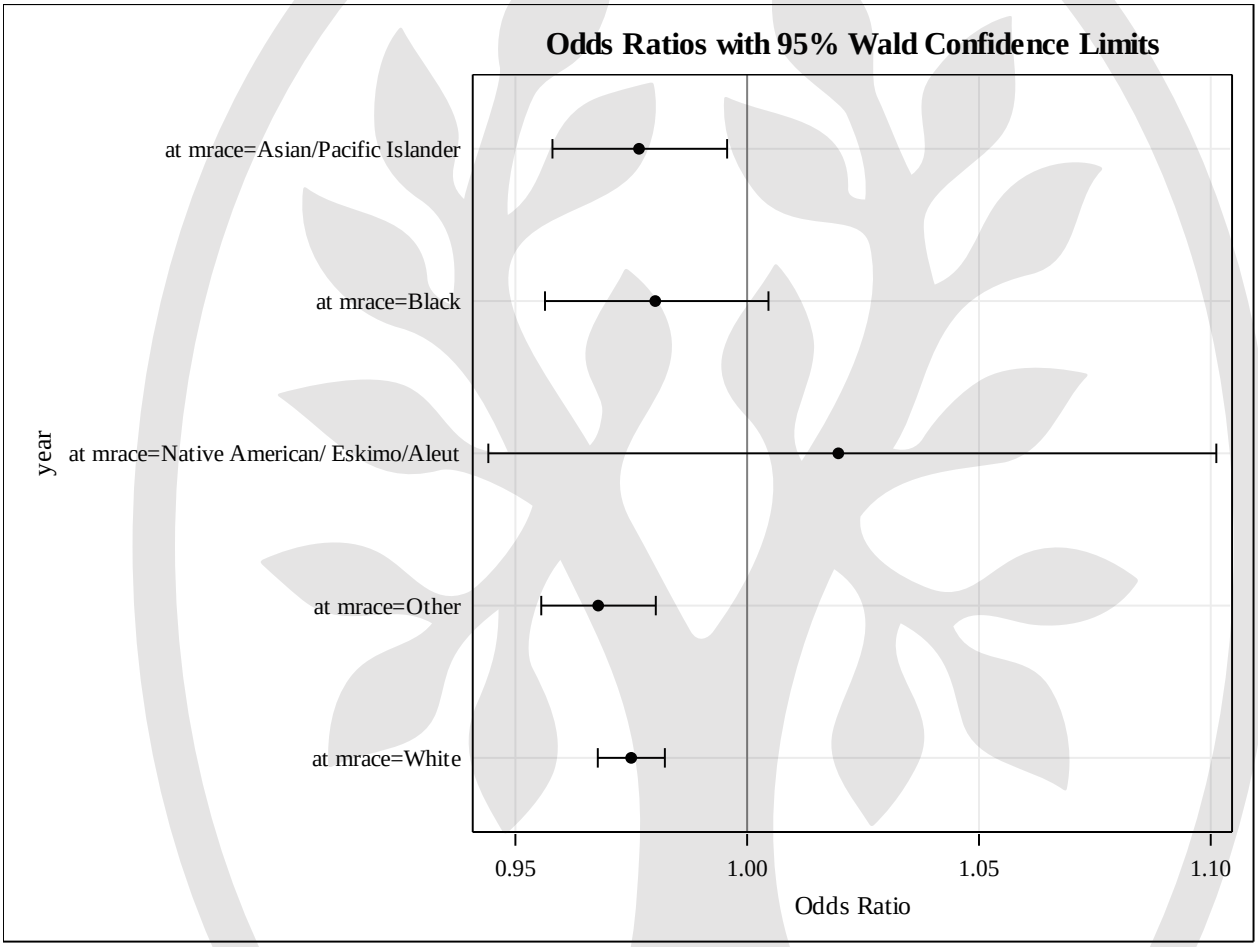
Joint Tests			
Effect	**DF**	**Wald Chi-Square**	**Pr > ChiSq**
year	1	22.0523	<.0001
mage3	2	1.3691	0.5043
year*mage3	2	1.3758	0.5026
mhisp	1	62.6366	<.0001
mrace	4	166.1265	<.0001
macro	1	5750.0201	<.0001
csect	1	1095.7214	<.0001
shoulder_dys	1	5864.3312	<.0001

C. Demographic groups experienced similar longitudinal trends

Consistent with the test statistics in part A, when we estimate odds ratios and 95% Confidence Intervals for year (as an independent variable) separately by each level of a tested demographic variable, we see a high degree of similarity in those estimates across the levels of that demographic variable, supporting the finding of homogeneity in the longitudinal trends across subgroups.

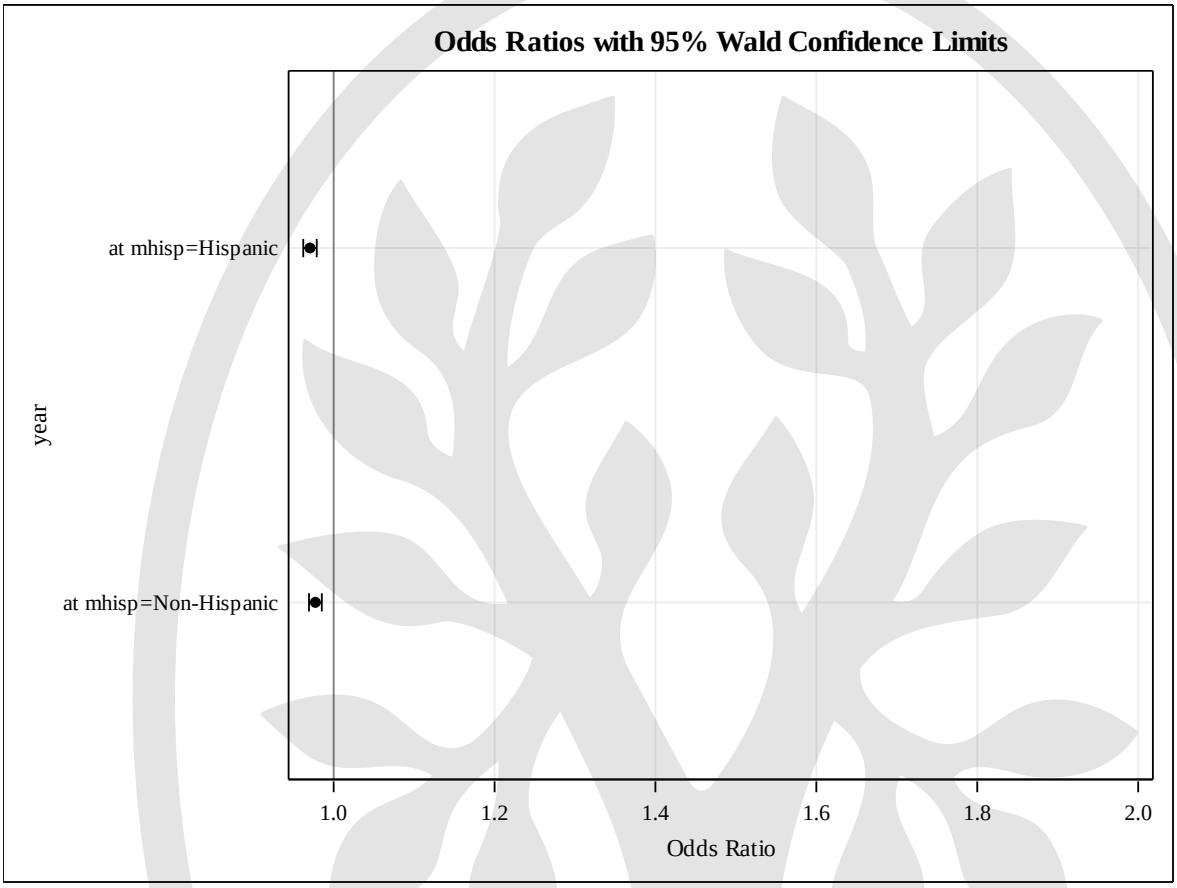
Race

Odds Ratio Estimates and Wald Confidence Intervals			
Odds Ratio	**Estimate**	**95% Confidence Limits**	
year at mrace=Asian/Pacific Islander	0.977	0.958	0.996
year at mrace=Black	0.980	0.956	1.005
year at mrace=Native American/ Eskimo/Aleut	1.020	0.944	1.101
year at mrace=Other	0.968	0.956	0.980
year at mrace=White	0.975	0.968	0.982



Ethnicity

Odds Ratio Estimates and Wald Confidence Intervals			
Odds Ratio	**Estimate**	**95% Confidence Limits**	
year at mhisp=Hispanic	0.971	0.962	0.979
year at mhisp=Non-Hispanic	0.977	0.969	0.985



Age

Odds Ratio Estimates and Wald Confidence Intervals			
Odds Ratio	**Estimate**	**95% Confidence Limits**	
year at mage3=0	0.984	0.963	1.006
year at mage3=1	0.972	0.966	0.979
year at mage3=2	0.978	0.963	0.993